Bicycle Pedal Study

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Data was obtained for the comparison of a prototype bicycle pedal to a traditional pedal on 4 trained cyclist table 1.

Table 1. Characteristic of Subjects

Subjects	Gender	Age (yrs)	Height (in)	Weight (lbs)
1	M	49	71	192
2	M	34	69	167
3	F	46	63	118
4	M	49	72	198

Each subject was tested on separate days for efficiency and power. All test were arranged to avoid order effect of test results.

Efficiency Results

Net efficiency was calculated from the amount of oxygen consumed during a 15 minute ride at a workload of 900 kgm for males and 750 kgm for the female subject. Each subject after resting data was obtained was instructed to warm up for a period of five minutes. After the warmup subjects were allowed to recover until resting values were obtained. Each subject then rode for 15 minutes at prescribed workload, exercise post oxygen consumption (EPOC) was measured during recovery for 10 minutes. Heart rates were continually monitored throughout the data collection using a Polar heart rate monitor. Oxygen consumption was measured using the Cosmed K4 portable oxygen and carbon dioxide analyzer. Energy cost (kcal) was calculated using the energy equivalents for respiratory exchange ratios. Net energy was calculated by subtracting the resting average energy value. Net efficiency for each subject (figure 1.) was plotted for subject comparison.

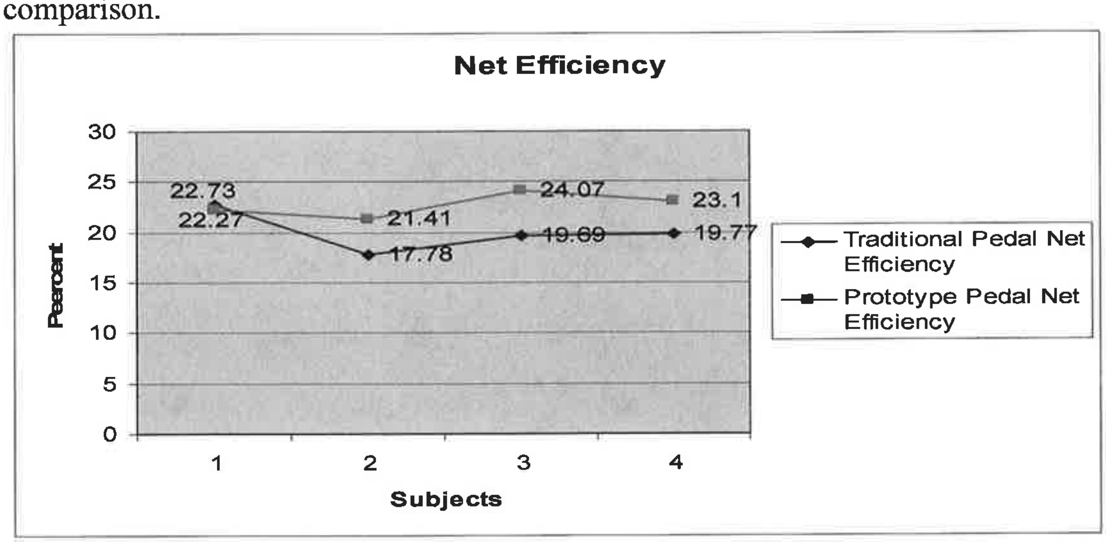


Figure 1. Net Efficiency

The results for net efficiency by subject indicated that 3 of the 4 subjects were more efficient when pedaling with the prototype pedal. The mean net efficiency (figure 2) was 22.7125 % for the prototype pedal and 19.9925 for the traditional pedal.

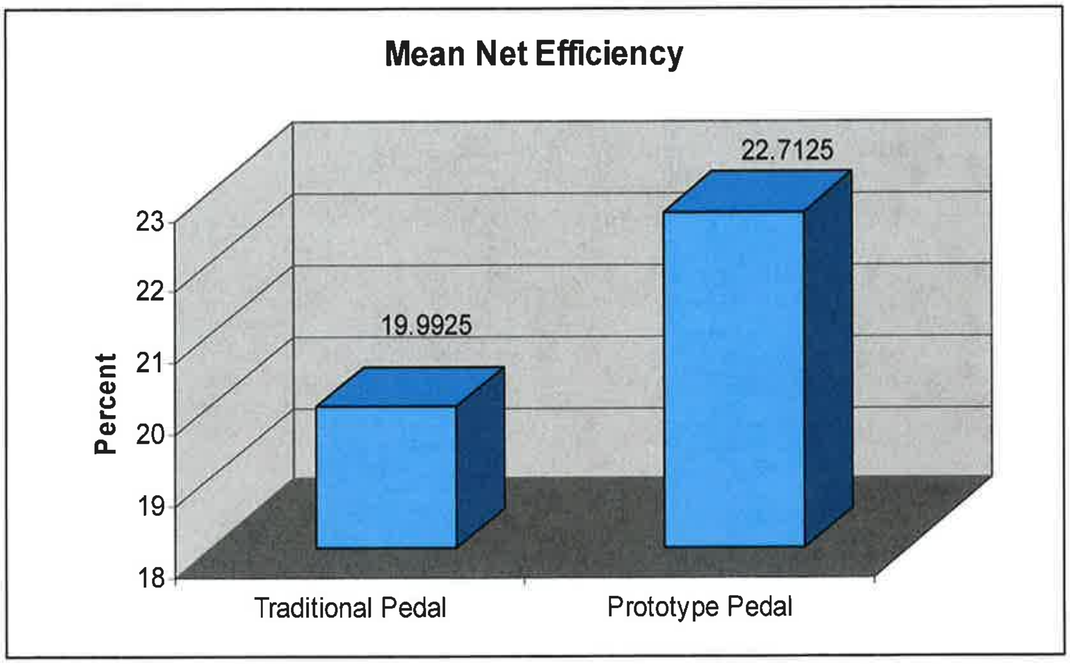
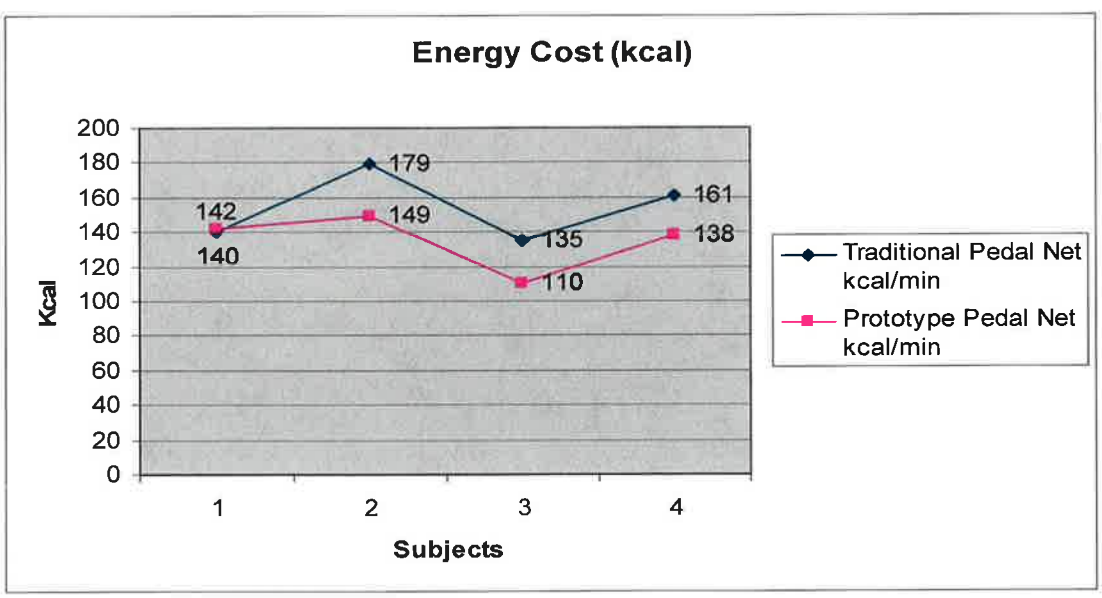


Figure 2. Mean Efficiency for Group.

Energy Cost

The total energy cost of the 15 minute ride was again lower for 3 of 4 cyclist, when using the prototype pedal (figure 3).



The mean heart rate and total energy cost was found to be lower for the prototype pedal compared to the traditional pedal (figure 4.).

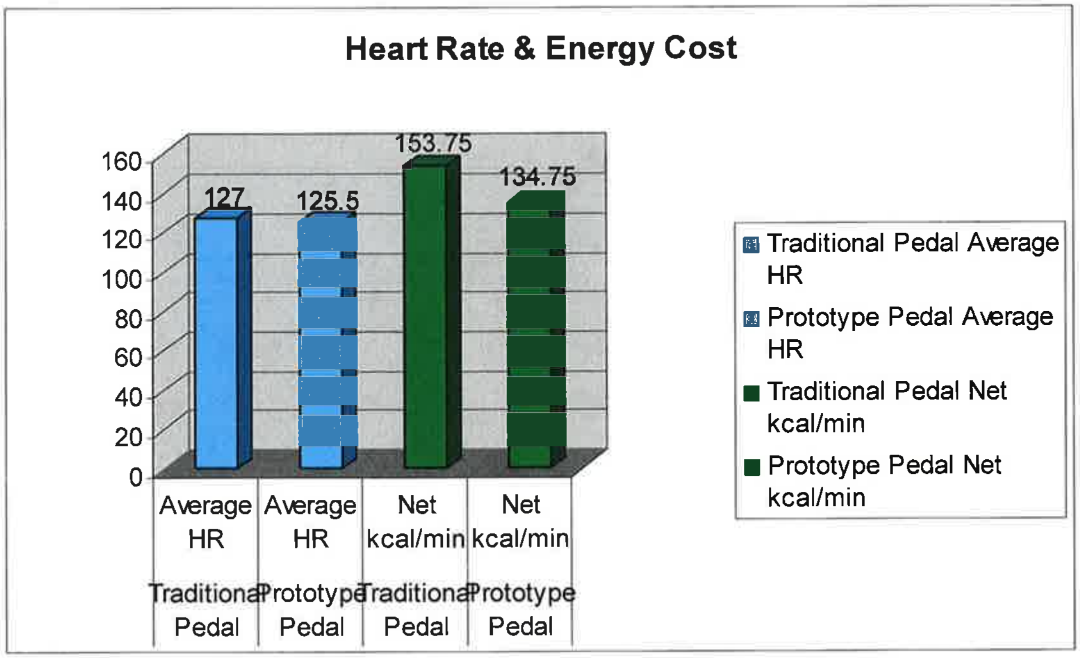


Figure 4. Heart rate and total Energy Cost Comparison.

Oxygen Deficit

The oxygen deficit is defined as the difference between the oxygen consumed during the defined period of exercise and the amount that would have been consumed if it were possible to supply all of the oxygen immediately from the start of the ride. It was found that the oxygen debt was significantly lower using the prototype pedal in all cyclist. This indicates that the cyclist achieved steady state earlier in the ride (figure 5).

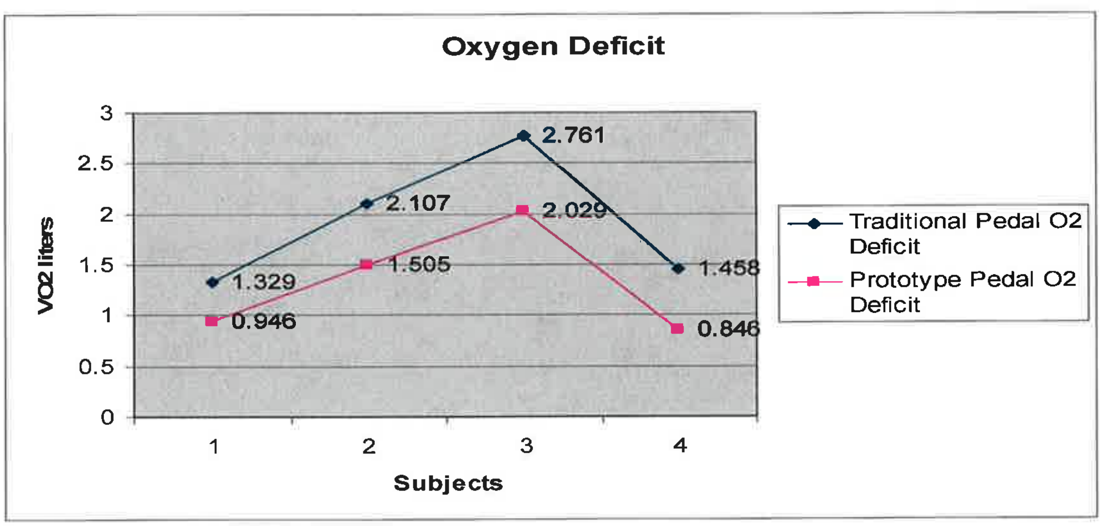


Figure 5. Oxygen deficit.

Exercise Post Oxygen Consumption

Exercise Post Oxygen Consumption (EPOC) is the amount of oxygen consumed in the post-exercise recovery period to reserve the anaerobic reactions of the exercise period. Quantitatively, it is the net oxygen consumption of the recovery period. Three of 4 cyclist showed increased recovery from the exercise when using the prototype pedal (figure 6).

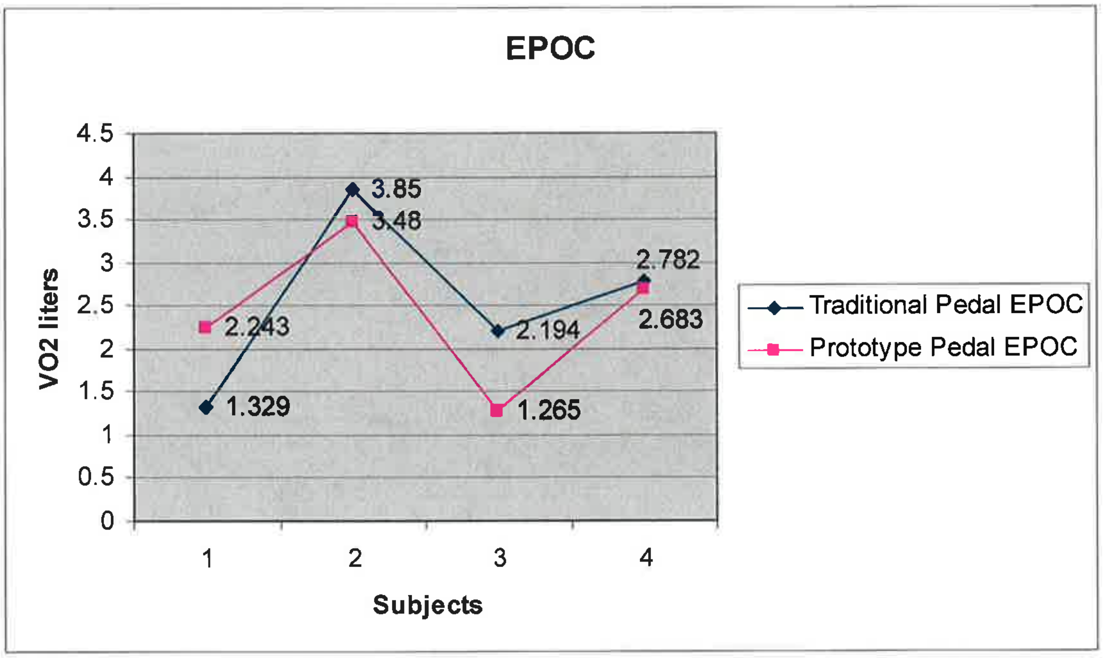


Figure 6. Recovery Oxygen consumption.

When looking at the group for oxygen deficit and exercise post oxygen consumption it was found that the oxygen deficit for the group was statistically significant p=.05 for the prototype pedal when compared to the traditional, and the recovery was slightly faster for the prototype pedal (figure 7).

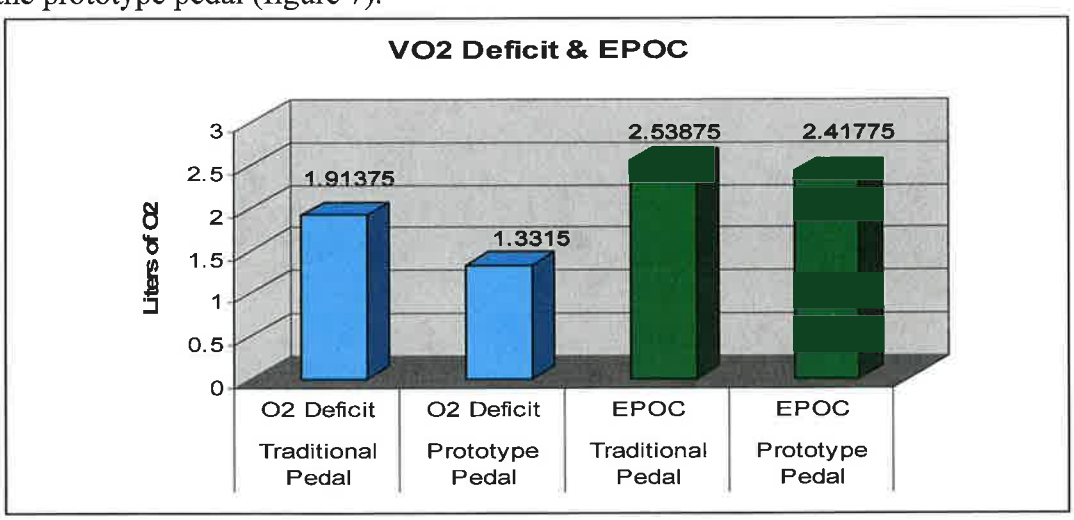


Figure 7. VO2 deficit and EPOC.

Statistical Analysis of Data

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	NetEffTRADITION	19.9925	4	2.04370	1.02185
	NetEffPPROTOTYPE	22.7125	4	1.13802	.56901
Pair 2	O2deficitTRADITIONAL	1.9138	4	.65950	.32975
	O2deficitPROTOTYPE	1.3315	4	.54801	.27400
Pair 3	EPOCTRADITIONAL	2.5388	4	1.05844	.52922
	EPOCPROTOTYPE	2.4178	4	.92342	.46171
Pair 4	HRTRADITIONAL	127.0000	4	24.12468	12.06234
	HRPROTOTYPE	125.5000	4	26.29956	13.14978
Pair 5	KCALTRADITIONAL	153.7500	4	20.25463	10.12731
	KCALPROTOTYPE	134.7500	4	17.11481	8.55740

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	NetEffTRADITION & NetEffPPROTOTYPE	4	.168	.832
Pair 2	O2deficitTRADITIONAL & O2deficitPROTOTYPE	4	.988	.012
Pair 3	EPOCTRADITIONAL & EPOCPROTOTYPE	4	.705	.295
Pair 4	HRTRADITIONAL & HRPROTOTYPE	4	.946	.054
Pair 5	KCALTRADITIONAL & KCALPROTOTYPE	4	.719	.281

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	NetEffTRADITION - NetEffPPROTOTYPE	-2.72000	2.16550	1.08275	-6.16580	.72580	-2.512	3	.087
Pair 2	O2deficitTRADITIONAL - O2deficitPROTOTYPE	.58225	.14537	.07269	.35093	.81357	8.010	3	.004
Pair 3	EPOCTRADITIONAL - EPOCPROTOTYPE	.12100	.77170	.38585	-1.10695	1.34895	.314	3	.774
Pair 4	HRTRADITIONAL - HRPROTOTYPE	1.50000	8.58293	4.29146	-12.15736	15.15736	.350	3	.750
Pair 5	KCALTRADITIONAL - KCALPROTOTYPE	19.00000	14.30618	7.15309	-3.76432	41.76432	2.656	3	.077

Power Measurements

Purpose of Test
To assess anaerobic power and anaerobic capacity of muscles involved during a short, super maximal bout of cycling.

Energy for various intensities of exercise is generated from the ATP-PCr Energy System, Anaerobic Glycolysis, the Aerobic Energy System, or a combination of two or more of these energy systems.

The ATP-PCr Energy System provides adequate amounts of energy to fuel approximately the first 10-15 seconds of all out exercise. When this energy system is engaged, muscle actions are powered by: 1) the limited intramuscular stores of ATP, and 2) resynthesized ATP.

At approximately 10-15 seconds into maximal exercise, intramuscular stores of ATP and PCr become depleted. At that time, working muscles employ Anaerobic Glycolysis to generate ATP. Anaerobic Glycolysis:

- Produces ATP anaerobically from muscle glycogen; and
- Can generate significant amounts of ATP between the first 30 seconds to 3 minutes of exercise.

The ATP-PCr Energy System and Anaerobic Glycolysis are referred to as anaerobic systems because they do not require oxygen to rapidly regenerate fuel during brief bouts of maximal exercise. Performance during bouts of exercise that require immediate generation of anaerobic power and in some cases the maintenance of anaerobic power for an extended period of time (e.g., 30 seconds) is highly dependent on the body's ability to generate ATP anaerobically.

Laboratory measurements of these anaerobic energy systems are warranted in order to predict performance of events requiring all-out maximal effort or to evaluate the efficacy of particular training regimens.

Maximal exercise tests of 30 seconds to 3 minutes in duration are primarily used to assess the body's ability to generate energy from anaerobic glycolysis. Anaerobic glycolysis has been shown to contribute to 49% of the energy production during a 30 second Wingate Cycle Ergometer test.

The 30 second Wingate Cycle Ergometer test is commonly used to assess the Lower body's muscular power.

Definition of Terms:

- Peak power output: **peak or highest power output generated during the entire test;**
- Average power output: **the average power output generated during the entire test.**
- Anaerobic capacity: **the total amount of work accomplished during the entire test.**
- Anaerobic fatigue: **the percentage decline in power output during the test.**

Measurement of:

Peak power output- peak power is usually achieved within the first 5 or 10 seconds of the test and reflects the subject's ability to generate energy from ATP-PCr energy system.

Average power output- The average power output for the entire test typically reflects the subject's ability to generate energy from anaerobic glycolysis.

Anaerobic capacity and Anaerobic fatigue- both reflect the subject's ability to generate energy from both energy systems over the entire duration of the test.

561.25

Example: The peak power output was 625 W and the lowest power output during the 30 seconds was 250 W. Calculate the anaerobic fatigue for this subject.

$$\textbf{Anaerobic fatigue} = \frac{625-250}{625} \times 100 \qquad \frac{375}{625} \times 100 = 60$$

During a 30 second Wingate test this subject's power output declined by 60%

Peak Power Output

Peak power is usually achieved within the first 5 or 10 seconds of the test and reflects the subject's ability to generate energy from ATP-PCr energy system. Three of the 4 subjects had higher power outputs when using the prototype pedal, the 4^{th} subject had the same power output for both pedals (figure 8). The lowest power output was the female cyclist, which is normally found between genders.

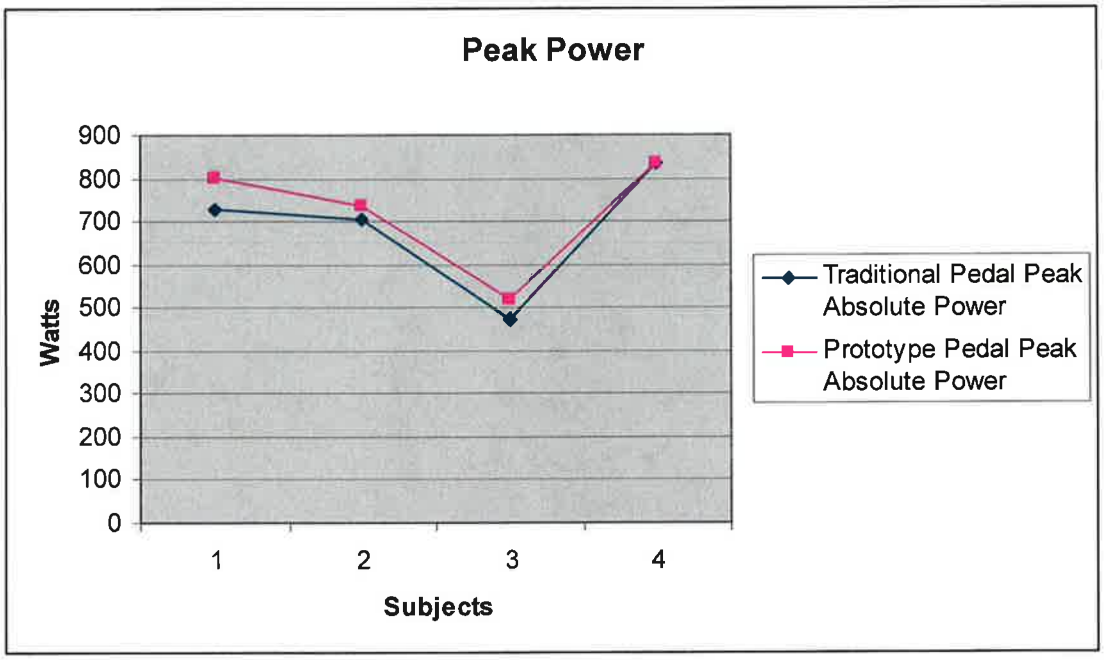


Figure 8. Peak Power Output by subject.

The group peak power output was approximately 40 Watts more using the prototype pedal (figure 9)

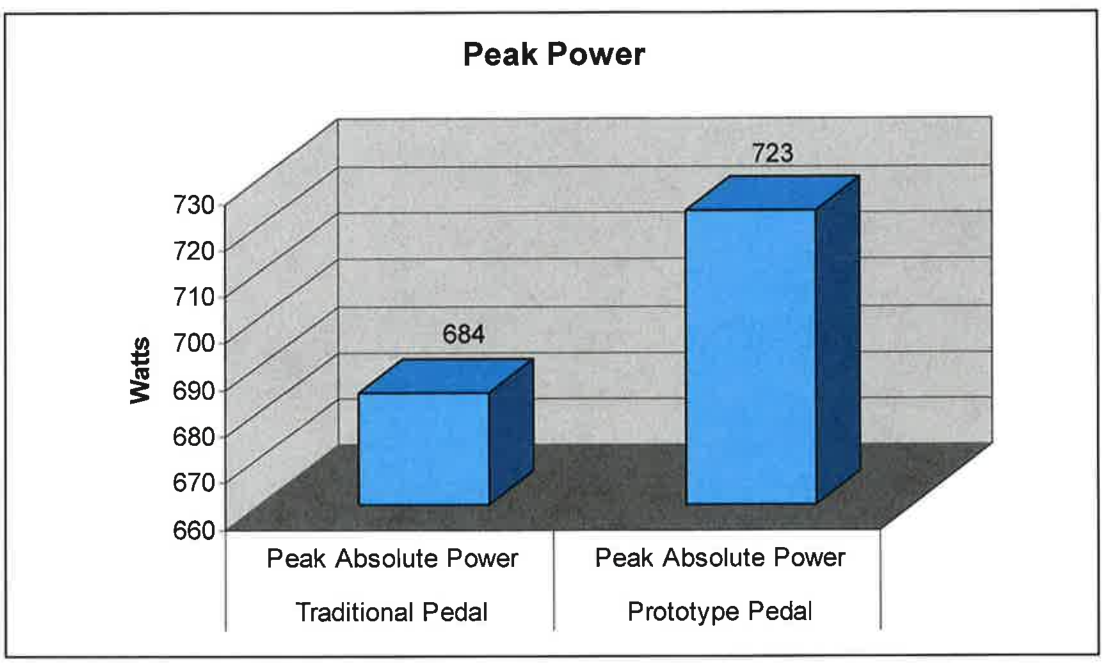


Figure 9. Group Peak Power Output

The average power output for the entire test typically reflects the subject's ability to generate energy from anaerobic glycolysis. The average power was higher using the prototype pedal (figure 10).

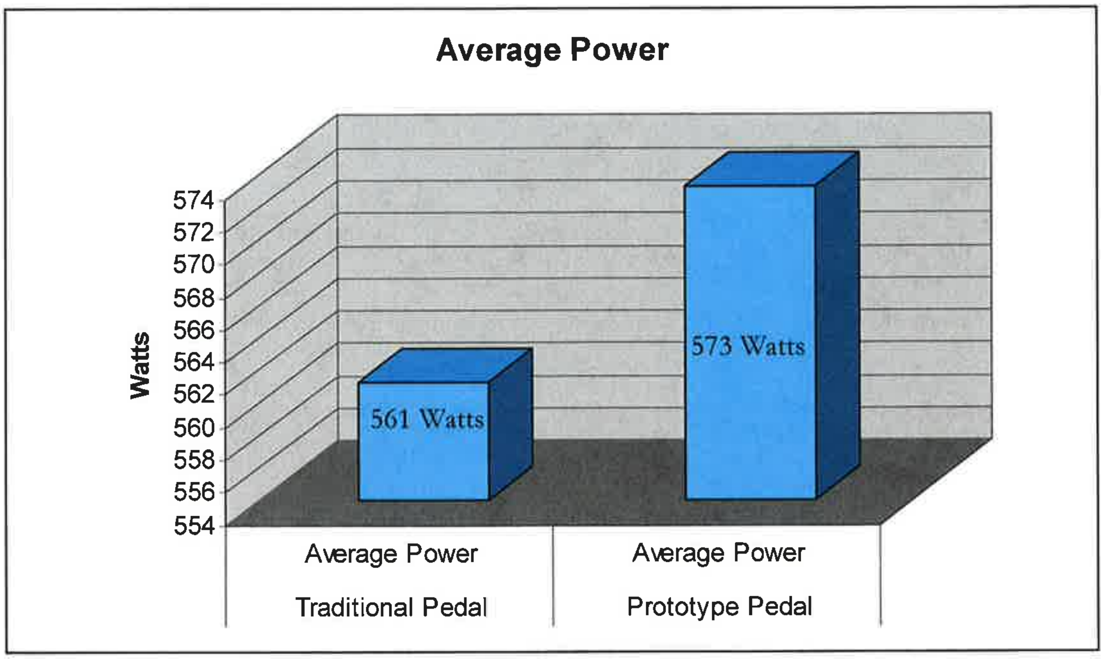


Figure 10. Average power output

Anaerobic fatigue is the percentage decline in power output during the test (figure 11& 12). It was found that the fatigue index was higher using the prototype pedal. This is expected since the prototype pedal produced the most power. Even though the power declined more from the peak the average power was stile greater.

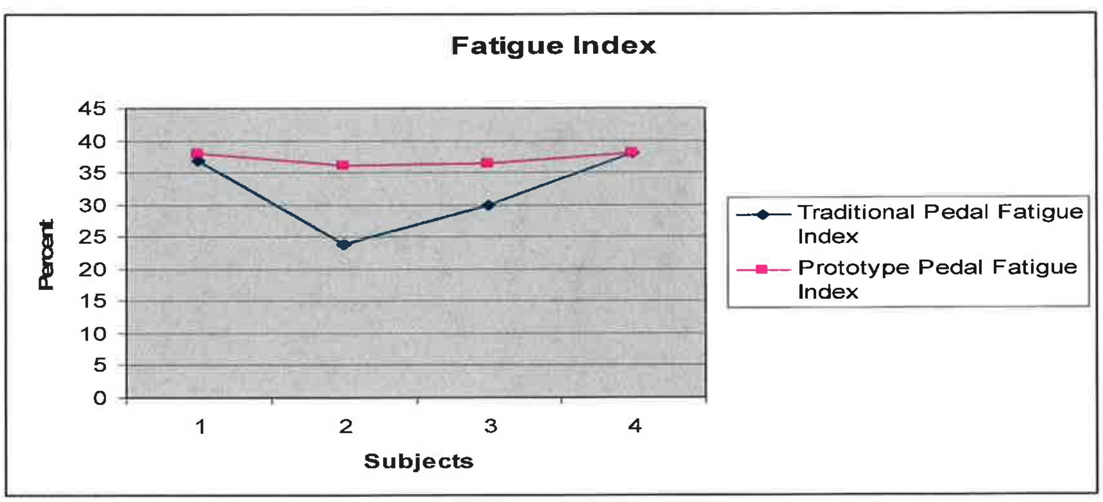


Figure 11. Fatigue Index by subject

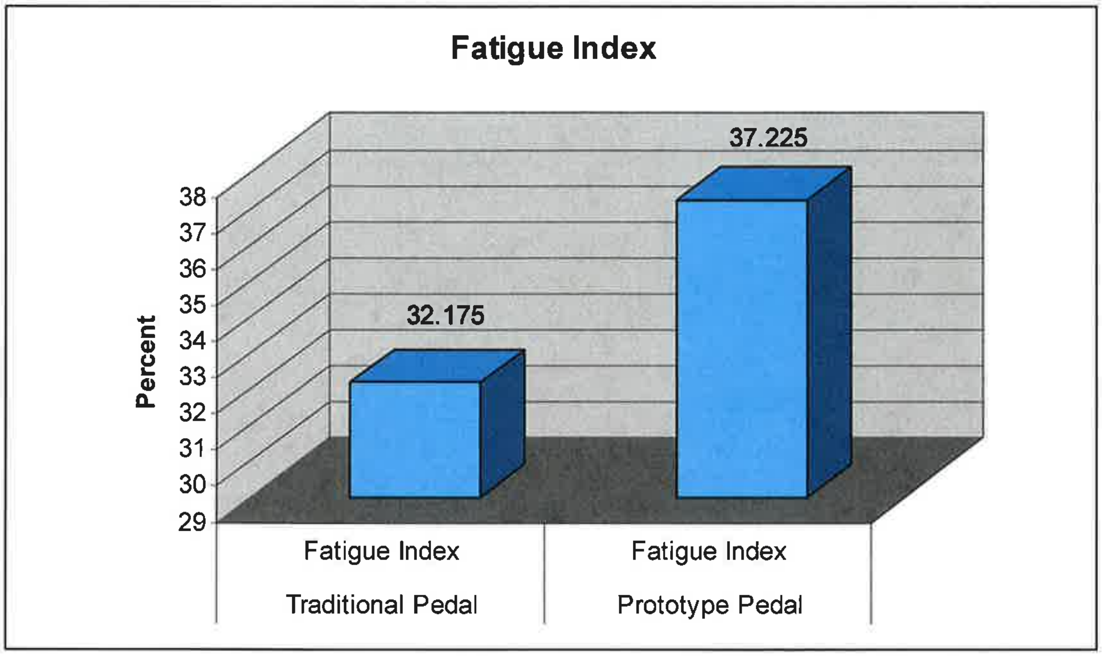


Figure 12. Group Fatigue Index.

Lactic acid is produced during anaerobic glycolysis work, it indicates the metabolic intensity. It was found that in all of the male subjects that lactate production was lower when using the prototype pedal, this is interesting since the power output was greater but lactate production was lower. The female subject was working relatively harder and produced greater lactate with the prototype pedal (figure 13).

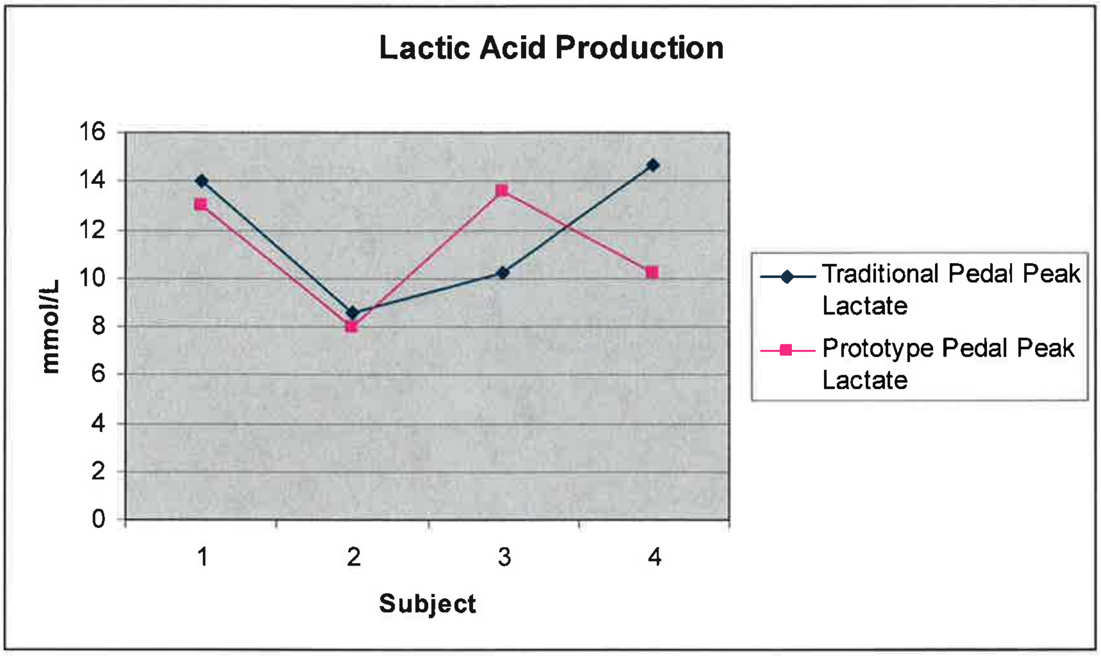


Figure 13. Lactic Acid Production.

As a group lactic acid production was less using the prototype pedal (figure 14).

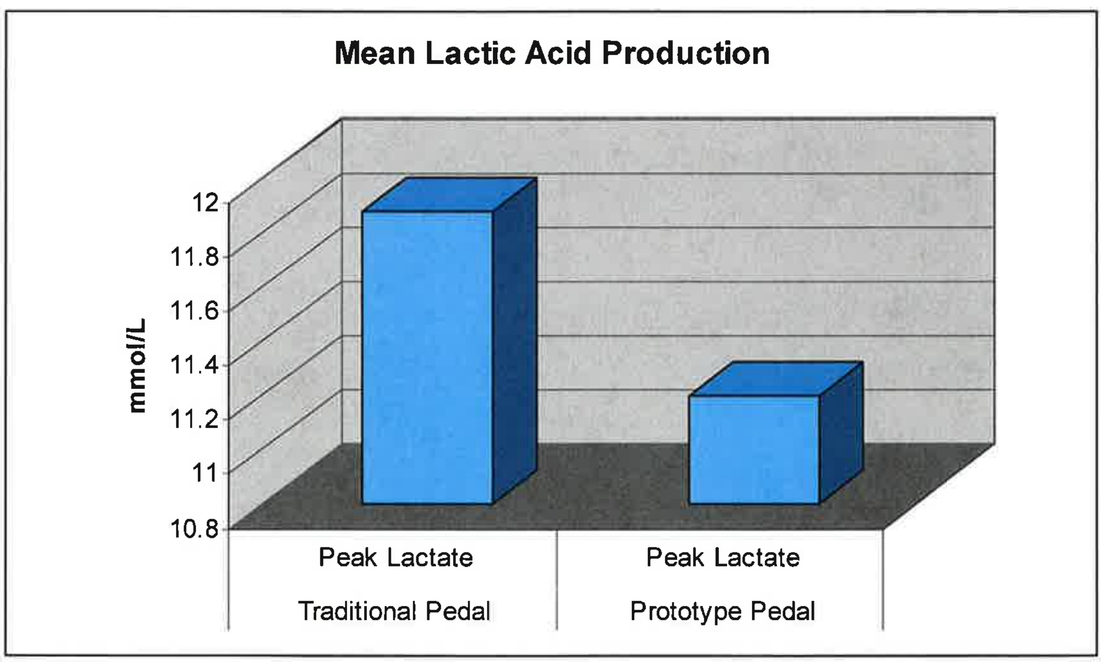


Figure 14. Lactic Acid Production.

Statistical Analysis

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PEAKPOWERTRADITIONAL	684.0000	4	152.88122	76.44061
	PEAKPOWERPROTOTYPE	723.0000	4	142.52719	71.26360
Pair 2	AVERAGEPOWERTRADITIONAL	561.2500	4	115.26600	57.63300
	AVERAGEPOWERPROTOTYPE	573.2500	4	107.01830	53.50915
Pair 3	FATIGUEINDEXTRADITIONAL	32.1750	4	6.61734	3.30867
	FATIGUEINDEXPROTOTYPE	37.2250	4	1.01119	.50559
Pair 4	LACTATETRADITIONAL	11.8750	4	2.94548	1.47274
	LACTATEPROTOTYPE	11.2000	4	2.59743	1.29872

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PEAKPOWERTRADITIONAL & PEAKPOWERPROTOTYPE	4	.980	.020
Pair 2	AVERAGEPOWERTRADITIONAL & AVERAGEPOWERPROTOTYPE	4	.931	.069
Pair 3	FATIGUEINDEXTRADITIONAL & FATIGUEINDEXPROTOTYPE	4	.935	.065
Pair 4	LACTATETRADITIONAL & LACTATEPROTOTYPE	4	.325	.675

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PEAKPOWERTRADITIONAL - PEAKPOWERPROTOTYPE	-39.00000	31.57003	15.78501	-89.23496	11.23496	-2.471	3	.090
Pair 2	AVERAGEPOWERTRADITIONAL - AVERAGEPOWERPROTOTYPE	-12.00000	41.98412	20.99206	-78.80611	54.80611	-.572	3	.608
Pair 3	FATIGUEINDEXTRADITIONAL - FATIGUEINDEXPROTOTYPE	-5.05000	5.68302	2.84151	-14.09295	3.99295	-1.777	3	.174
Pair 4	LACTATETRADITIONAL - LACTATEPROTOTYPE	.67500	3.23252	1.61626	-4.46866	5.81866	.418	3	.704

Summary:

In summary it is evident that the prototype pedal was more efficient, produced more power when compared to the traditional pedal. The prototype pedal showed lower oxygen deficit and greater recovery when used compared to the traditional pedal. Lactic acid production was also lower during maximal power output.

The prototype pedal did have a greater fatigue index during power test, although this looks like a negative the average power was still higher than the traditional pedal indicating more power output throughout the test.

My Opinion: I believe the prototype pedal is an innovative device that could provide an advantage for cyclist. It would be more efficient on the straight and provide more power on the hills, this could revolutionize cycling.